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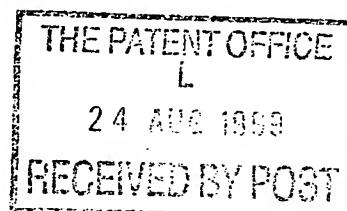
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4. Title of the invention

MICRO-BRIDGE STRUCTURE

5. Name of your agent (*if you have one*)

Barker Brettell

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MICRO-BRIDGE STRUCTURE

This invention relates to a method of making a micro-bridge and a new
5 structure for a micro-bridge, such as may be used in imaging devices to detect incident radiation. The invention arose from the field of thermal imaging, but is not necessarily limited to that field.

Infra-red imaging cameras based on two-dimensional arrays of thermal
10 detectors are attractive due to their near ambient temperature operation. Thermal detectors used for infra-red imaging rely on the temperature change of the sensing material due to absorption of infra-red radiation. A 1°C temperature change in the scene leads to a temperature change of about 0.001°C temperature change within the detector and it is therefore
15 important to try and maximise the amount of radiation absorbed.

The sensing material has a temperature dependant property which allows the magnitude of the change in temperature to be detected, amplified and displayed using electronic circuitry. Examples are pyroelectric arrays,
20 which rely on the change in electrical polarisation with temperature which occurs in ferroelectric materials, and resistance micro-bolometer arrays which utilise the change in electrical resistance with temperature which occurs in some materials

25 In all types of thermal detector it is advantageous to maximise the rise in temperature of the sensing material due to the absorption of infra-red radiation. The temperature rise is reduced by any thermal conduction mechanism which takes heat from the sensing material. This results in detector designs which maximise the thermal isolation of the sensing
30 material. The requirements for electrical read-out and mechanical rigidity

mean that, for most practical detectors, a physical connection is required to the sensing material.

Infra-red (IR) imaging relies on the fact that all objects radiate energy
5 with a peak wavelength depending on their temperature. For ambient temperature objects this peak wavelength is in the Infra-red at about 10 μ m. Hotter objects radiate more intensely. IR imaging typically involves using lenses, which may be of Germanium, to collect and focus this radiation onto an array of sensitive elements placed in the focal plane
10 of the optics. The elements are normally micro-capacitors or micro-resistors (micro-bolometers) whose characteristic parameter (charge or resistance respectively) depends on the temperature. The micro-bolometers are usually formed on silicon substrates using "micro-machining techniques". This involves depositing and lithographically
15 patterning an active layer over a sacrificial layer that is finally etched away to leave a free-standing, thermally isolated structure.

Such a structure is shown in Figure 1 of the accompanying drawings wherein legs 2, 4 support the main body of the element 1 above a substrate (not shown). The legs 2, 4 ensure that mechanical support is provided for the main body but with low thermal conductivity to the substrate.

Each element generates an electric signal proportional to its temperature
25 that, in turn, depends on the intensity of the IR energy absorbed by it or its adjacent layer. The electrical signals must then be read out using a circuit that will both filter and amplify.

Traditionally the quantum devices used to detect IR radiation have
30 required cooling to liquid nitrogen temperatures. The "uncooled"

technology described herein operates at room temperatures. Since IR radiation is not obscured by smoke this technology is also useful in fire-fighting applications. There are also applications where it is not necessary to form high-resolution images. The IR sensitive elements can
5 be used for simple "intruder detectors" or fire detectors.

Presently there are two basic forms of the resistance micro-bridge. Firstly, there is the homogeneous bridge type, as shown in section in Figure 2a of the accompanying drawings. In this type of bolometer the
10 bridge is formed from a material whose properties change as the temperature changes through radiation being absorbed. The change in material properties is determined in some manner, perhaps by measuring a change in current passing through the bridge. The skilled person will appreciate that whilst the homogeneous bridge can work satisfactorily well
15 its performance may not be as efficient as desired.

The second class of micro-bridge can be termed "film-on-support" and provides a temperature dependent material (which may be resistive) as a film above a supporting bridge. Such a film on support micro-bridge is
20 shown in section in Figure 2b of the accompanying drawings. The bridge absorbs incident thermal radiation of the wavelengths of interest causing a temperature change within the bridge which effects the resistance of the resistive material. Generally the resistive material will be a metal which when positioned above the bridge reflects some of the incident radiation
25 reducing the sensitivity of the micro-bolometer. Further, the provision of the metal on top of the bridge requires vias to be fabricated through the bridge necessitating further processing steps.

An example of a micro-bridge structure is shown in the Journal of
30 Microelectromechanical systems Vol.5 No. 4 December 1996 in an article

by Shie, Chen, et al. However, the micro-bolometer shown therein is fabricated by a process which is somewhat more complicated than may be desired. The bridge is formed over a V groove which is fabricated using an anisotropic wet etch.

5

A further micro bridge structure is also shown in US 5 698 852 wherein a Titanium layer provides the resistor on the underside of a bridge formed from a layer of SiO₂. However, this document shows the resistive bolometer portion sandwiched between two SiO₂ layers. The micro-

10 bolometer shown in this US patent has a much more complex structure than that described herein. It will be appreciated that simplifying the structure and processing steps reduces the cost of the device and also helps to increase the yield.

15 According to a first aspect of the invention there is provided a method of fabricating a micro-bridge device onto a substrate including the steps:

a. providing a sacrificial material on a surface region of the substrate; -

b. patternwise etching the sacrificial material;

20 c. providing a sensing material on a surface region of the sacrificial material;

d. providing a support material on a surface region of the sensing material; and

e. removing the sacrificial material leaving the support material,

25 with the sensing material on its lower surface, substantially free standing above the substrate.

This method is advantageous because it provides a micro-bridge structure by a method that has fewer processing steps than prior art methods. The

30 skilled person will appreciate that the reduction of the number of

processing steps is greatly advantageous because it will tend to increase the yield of the fabrication process and will also reduce the cost of devices fabricated by the method.

- 5 The sensing material may be a conductive material. Such a material is suitable for providing a micro-bridge structure in which a change of resistance is measured. Preferably the micro-bridge device is a micro-bolometer wherein the sensing material provides the resistor.
- 10 Alternatively, the sensing material may be a ferro-electric material. Such a material is suitable for providing a micro-bridge structure in which a change of charge is measured.

Preferably, the substrate has electronic circuitry provided therein. This is
15 advantageous because it allows processing electronics to be provided for processing the signal from the micro-bridge and allows a single package to be provided containing both the micro-bridge and processing electronics. The provision of optimum processing electronics may not be possible in some prior art structures. For instance, in the paper by Shie,
20 Chen, et al. the V-groove provided underneath the bridge structure is likely to prevent the provision of such electronics beneath the plan area of the bridge device - the region of the substrate where the electronics would be provided is etched away. Therefore, the structure provided by the
method may provide an area beneath the micro-bridge device in which
25 signal processing electronics may be located.

Most preferably the method is compatible with CMOS processing steps. This is advantageous because it allows standard fabrication processes to be used which will generally reduce the cost of devices fabricated
30 according to the method.

- Conveniently step b of the process includes providing vias through the sacrificial material allowing connections to the electronic circuitry in the substrate. Such a step is a convenient way of providing the single package with processing electronics and micro-bridge. The skilled person will appreciate that the vias may be defined using a conventional photoresist to pattern the sacrificial layer or by the use of a photo-imageable polymer as the sacrificial layer.
- 10 In one embodiment the sacrificial material is polyimide which may be spin deposited and cured. The sacrificial material may be applied to a thickness of about $3\mu\text{m}$. However, in alternative embodiments the sacrificial material may be applied to a thickness of between about $1.5\mu\text{m}$ and about $6\mu\text{m}$, or may be between about $2\mu\text{m}$ and about $4.5\mu\text{m}$. It will
15 be appreciated that the thickness of the sacrificial material governs the height of the sensing material above the substrate in the final micro-bridge structure.

The method may include the steps of using an etch solvent to ensure that
20 all resist layers are removed subsequent to deposition of the sacrificial material. The etch solvent may be EKC.

The sensing material may be titanium (Ti). Titanium is advantageous because of its change of characteristics with temperature and also due to
25 its low noise levels. Further, titanium has a high resistivity which may allow the design to be optimised for CMOS circuitry more easily than other sensing materials. The skilled person will appreciate that for two equal portions of the material, the portion with the higher resistivity will have the higher resistance.

The sensing material may be deposited by sputter deposition, providing a convenient method which is CMOS compatible. The sensing material may be deposited to a thickness of about $0.2\mu\text{m}$.

- 5 However, the skilled person will appreciate that other thicknesses may be suitable. For instance the sensing material may be provided to a thickness in the range of about $0.05\mu\text{m}$ to about $0.3\mu\text{m}$, or may be from about $0.1\mu\text{m}$ to about $0.25\mu\text{m}$. If the micro-bridge device is a micro-bolometer the sensing material may form the resistor. It is desirable that the
- 10 resistance of this resistor is relatively high because this makes the signal provided from the micro-bolometer easier to process. Providing the sensing material in this range provides suitable resistances. Thicknesses greater than this range may tend to reduce the resistance too much.
- 15 The thicknesses and resistances described herein are particularly suitable when the sensing material is Titanium. If the sensing material is another material other thicknesses may be applicable.

- 20 In alternative embodiments the sensing material may be amorphous silicon, vanadium oxide, platinum, nickel, aluminium, or an alloy of any one of the aforementioned metals each of which provides suitable properties

-
- 25 The sensing material may have a sheet resistance of $3.3\Omega/\text{sq}$.
 - Alternatively, the sensing material may have a sheet resistance of about $1.5\Omega/\text{sq}$ to about $6\Omega/\text{sq}$, or may be of about $2.5\Omega/\text{sq}$ to about $4.5\Omega/\text{sq}$.

-
- 30 Conveniently step C. of the method includes the further step of removing the sensing material from optical alignment targets (OAT) provided on the substrate for alignment of subsequent layers. Such a step is advantageous

because it simplifies the remaining steps of the method and makes it easier to position the remaining layers. It will be clear to the skilled person that OAT's are necessary when a wafer stepper is used.

- 5 Step b of the method may also include the step of removing the sacrificial material from OATs provided on the substrate. Such a step is particularly advantageous should the sacrificial material be a material other than silicon dioxide.
- 10 Preferably the support material is deposited onto the surface region of the sensing material. This deposition process may be provided by Plasma Enhanced Chemical Vapour Deposition (PECVD), Low Pressure Chemical Vapour Deposition (LPCVD), or by sputtering.
- 15 The support material may be deposited to a depth of about $1\mu\text{m}$. This depth is convenient because it provides sufficient structural rigidity. However, the skilled person will appreciate that a range of other thicknesses may be suitable. For instance the support material may have a thickness of about $0.05\mu\text{m}$, $0.1\mu\text{m}$, $0.5\mu\text{m}$ to perhaps about
- 20 $2\mu\text{m}, 3\mu\text{m}, 4\mu\text{m}, 5\mu\text{m}$.

Preferably, the method applies the support material to an accuracy of about $\pm 10\%$. It will be appreciated from the discussions above that the detector must be thermally isolated from its surroundings. Generally this

- 25 is achieved by providing a bridge structure (of the support material) which is supported by a pair of legs. In such a structure the legs provide thermal contact between the bridge and the wafer or substrate. Having the legs too thick is disadvantageous because more heat is conducted from the wafer or substrate to the bridge which reduces the sensitivity of the
- 30 micro bridge device. If the legs are too thin then there is not enough

mechanical support for the bridge structure. There is therefore a compromise between providing rigid supports and providing thermal isolation.

- 5 The skilled person will appreciate that the micro bridge structure may be provided with a number of legs other than two. The micro bridge structure may be provided with 1,3,4,5,6,7 or more legs.

10 The method may comprise applying the support material to have a thickness of about $\frac{1}{4}\lambda$ where λ is the wavelength of the incident radiation of interest within the support material. The skilled person will appreciate that the wavelength of the radiation will change according to the material in which it is travelling. Applying the support material to this thickness is advantageous because it causes destructive interference of radiation of
15 the wavelength of interest being reflected from the bottom surface of the support material with radiation incident on the bridge. This destructive interference promotes energy absorption and increases the temperature rise of the support material due to the incident radiation of the wavelengths of interest.

20

Alternatively, or additionally, the method may comprise providing the sacrificial material to a depth of about $\frac{1}{4}\lambda$. Thus, when the sacrificial material is removed the gap underneath the sensing material is substantially $\frac{1}{4}\lambda$ of the wavelength of the incident radiation. Again, this

- 25 leads to destructive interference of the incident and reflected radiation increasing the efficiency of the device. The skilled person will appreciate that the wavelength of the radiation which it is desired to detect is different in the material of the bridge and in free space. The gap underneath the sensing material and the support material may have
30 different thicknesses despite both being substantially equal to $1/4$

wavelength in thickness.

The support material is conveniently patterned and etched to provide the necessary structures. Preferably, the resists used to pattern and etch the
5 support material are removed by an etch solvent, which is conveniently EKC.

In one embodiment the support material is a silicon oxide which is advantageous because it is easy to provide using CMOS processing steps
10 and readily absorbs radiation with a wavelength of about $8\mu\text{m}$ to $14\mu\text{m}$ which as discussed previously is the wavelength which is conveniently monitored by the micro-bridge device. It is advantageous that the support material absorbs the radiation to maximise the temperature change of the support material due to incident radiation of the desired wavelength. The
15 skilled person will appreciate that for wavelengths other than $8\mu\text{m}$ - $14\mu\text{m}$ other materials which absorbs the wavelengths of interest may be advantageous.

The method may include the further step of providing a reflective layer on
20 a surface region of the substrate. Such a layer may further enhance the efficiency with which the micro-bridge structure absorbs incident radiation.

The reflective layer may be provided on a surface region of the substrate
25 before the sacrificial layer providing a convenient way of positioning the reflective layer. It will be appreciated that such a method provides a micro-bridge structure with the reflective layer provided on a top region of the substrate with the micro-bridge structure substantially suspended above the reflective layer.

Conveniently the method provides the reflective layer from a metal which may be any one of the following: Aluminium, titanium, nichrome, platinum, nickel or an alloy of any of these metals.

- 5 The reflective layer may be provided by sputtering, evaporation or any other suitable technique as will be appreciated by the person skilled in the art.

- Conveniently the sacrificial material is removed by ashing which may be
10 performed in an oxygen plasma, providing an effective process for removing the sacrificial material without interfering with the layers covering the sacrificial material.

- After step e. of the method a thermal anneal is preferably performed on
15 the substrate. The thermal anneal is beneficial because it preserves the elevated value of the temperature coefficient of the resistance of the Ti, and may ensure that contacts within the circuits are formed correctly, etc. The thermal anneal may be provided by a rapid thermal annealing process or an industry standard furnace anneal.

20

- The sensing material may be provided in tracks. Preferably the method comprises providing the tracks such that incident radiation having a specific polarisation cannot pass through the tracks. This may be achieved by arranging the tracks in a manner to block the passage of
25 radiation having a polarisation. In particular, the tracks may be provided such that they have lengths running in directions transverse to one another. The tracks may be provided with substantial lengths running in directions parallel to one another, or may be transverse one another, or may be orthogonal one another. In other embodiments the method may
30 comprise providing tracks having curved portions.

A matching layer may be provided in a region above the support material, adapted to absorb incident radiation. The matching layer may be nickel chrome alloy and may be provided by evaporation, or may be sputtering.

5

- A matching layer is advantageous because it may match the refractive index of the micro-bridge structure to that of free space. The skilled person will appreciate that when a wavefront is incident upon a boundary of materials each with different refractive indexes a degree of reflection will occur. Clearly, if incident radiation of the wavelength in question is reflected then the signal produced in response to the radiation will be reduced. It is therefore advantageous to minimise the amount of reflection occurring at the micro-bridge upper surface.
- 10 15 The matching layer may be deposited until it has the required resistance per square. The resistance may be about $377\Omega/\text{square}$. Alternatively, the resistance may be in the range of about $250\Omega/\text{sq}$ to about $500\Omega/\text{sq.}$, or may be in the range of about $320\Omega/\text{sq.}$ to about $430\Omega/\text{sq.}$
- 20 The method may further comprise providing the micro-bridge structure within an encapsulated package. The encapsulated package may be filled with a gas having a low thermal conductivity (xenon is one example) or more preferably the encapsulated package may be evacuated.

-
- 25 According to a second aspect of the invention there is provided a micro-bridge structure having a substrate above which there is provided a support element of the micro-bridge structure, on the underside of the support element there is provided a sensing material, the sensing material being supported above the substrate by the support element but connected
30 at connecting regions to tracks on the substrate.

An advantage of such a structure is that it is simpler to fabricate than prior art devices and may therefore provide higher yields and cheaper devices.

5

Preferably, the support element comprises a region of silicon oxide (SiO_2). This is a convenient material to provide being readily achievable in CMOS processes and strongly absorbs electromagnetic waves at the wavelengths of interest.

10

The support element may be substantially square in plan, providing an efficient shape from which to provide an array of micro-bridge structures.

15

In one embodiment the support element is substantially square in plan and has dimensions of substantially $50\mu\text{m}$ for the sides of the support element. In alternative embodiments the support element may have sides in the range of about $25\mu\text{m}$ to about $100\mu\text{m}$, or may be in the range $35\mu\text{m}$ to about $75\mu\text{m}$.

20
25

The support element may be provided with leg portions adapted to suspend the support element above the substrate. Such leg portions are advantageous because of the thermal isolation they provide for the support element from the substrate. Thermal isolation is advantageous because the temperature changes which must be measured by the micro-bridge structure are of such a magnitude that they are likely to be lost if the thermal mass of the substrate is not excluded.

30

Conveniently, the sensing material is also provided on the underside of the leg portions. Such a structure is again convenient because it provides a structure wherein the sensing material on the support element can easily

be connected to circuit elements on the substrate.

Preferably the sensing material is a conductive material. In which case the sensing material may form a resistor.

5

Alternatively, the sensing material may be a ferro-electric material. In which case the sensing element may form the dielectric of a capacitor. Such structures are convenient because they provide means to measure temperature changes within the support element (i.e. a change in 10 resistance of the resistor, or change of charge in the capacitor formed by the capacitor dielectric).

The resistor may be connected to a CMOS transistor provided in the substrate. This provides a convenient structure with which to process the 15 information provided by the micro-bridge structure.

The transistor may be arranged as a switch providing a convenient structure with which to connect the resistor to processing electronics at the correct instant for its resistance to be measured.

20

The resistor may have a resistance of about $3k\Omega$. Alternatively, the resistor may have a resistance in the range of about $1.5k\Omega$ to about $6k\Omega$, or may be about $2k\Omega$ to about $4.5k\Omega$.

25 The sensing material may be a metal and in particular may be titanium which is convenient material to provide using CMOS compatible processes. Further, titanium exhibits a temperature dependent resistance which makes it particularly suitable for this application and has a relatively high resistivity. In alternative embodiments materials such as 30 amorphous silicon, vanadium oxide, platinum, nickel, aluminium, an alloy

of any one of the aforementioned metals may provide the sensing material.

Preferably the resistor is provided as a track on the support element. This
5 is advantageous because it allows the length of the resistor to be maximised which increases the value of the resistance which can be provided. Having a higher resistance is in itself advantageous because it may be simpler for the detecting electronics to process readings from a resistor with a higher value.

10

Conveniently the track has a meandering structure, which is a convenient structure to attempt to maximise the length of the track. Preferably the meandering structure has major portions in transverse directions. The transverse directions may be substantially perpendicular to one another.

15 Such transverse directions are advantageous because they may prevent radiation having a particular polarisation from passing through the sensing element without being absorbed.

The skilled person will appreciate that in some embodiments the thickness

20 of the support element is tailored to be substantially $\frac{1}{4}\lambda$ of the incident radiation within the material of the support element. Thus radiation of the wavelength of interest incident upon the support element may be reflected back toward a top surface of the support element by the lower surface and destructively interfere with the incident radiation of the

25 wavelength of interest. The provision of the sensing material on the underside of the support element may help this reflection process and ensuring that radiation of a particular polarisation may not pass may further enhance this reflection process.

30 Conveniently, the support element may have a thickness of substantially

one quarter of the wavelength of radiation of which is desired to measure. This is advantageous for the reasons outlined hereinbefore. Specifically, the support element may have a thickness of substantially $1\mu\text{m}$. In other embodiments the support element may have a thickness in the range of 5 about $0.5\mu\text{m}$ to $2\mu\text{m}$, or may be $0.75\mu\text{m}$ to $1.5\mu\text{m}$.

Alternatively, or additionally, the support element may be suspended above the substrate by substantially one quarter of the wavelength of the radiation which is desired to measure. This is also advantageous because 10 it will aid the absorption of the radiation.

Although much of the radiation will be reflected upwards by the sensing material on a lower surface of the micro-bridge structure, a small amount of radiation may pass through the micro-bridge structure. It may 15 therefore be advantageous to make the gap between the substrate and the micro-bridge structure $1/4$ of the wavelength of the radiation of interest so that destructive interference occurs below the lower surface of the micro-bridge structure. Some of the radiation passing through the micro-bridge will be reflected by the substrate back toward the micro-bridge structure. 20 Therefore, the path length of this double reflected light is $1/2$ wavelength across the gap between the micro-bridge and the substrate and destructive interference will occur at about the lower surface of the micro-bridge structure. This destructive interference will increase the absorption of the wavelengths of interest by the support element.

25

A reflective layer may be provided to further enhance the percentage of radiation that is reflected back to the micro bridge structure from the substrate after passing through the micro bridge structure. The reflective layer may be provided on a top region of the substrate below the gap 30 between the substrate and the micro-bridge structure.

Conveniently the reflective layer is fabricated from a metal which may be any one of the following: Aluminium, titanium, nichrome, platinum, nickel or an alloy of any of these metals.

5

The micro bridge structure may further comprise a matching layer which may be provided on an uppermost surface of the support element. Such a matching layer is advantageous because it is a further mechanism to ensure that the absorption of the incident radiation of the wavelength of interest is maximised. The matching layer may aid the structure to absorb radiation at the wavelengths of interest particularly strongly.

10

The skilled person will appreciate that when a wavefront passes between two media having some degree of reflection occurs. Therefore, the matching layer may match the refractive index of the micro-bridge to that of free space, which is advantageous because it may minimise the amount of reflection that occurs at an upper surface of the micro-bridge device.

15

According to a third aspect of the invention there is provided a transducer incorporating a micro-bridge structure according to a second aspect of the invention.

20

The transducer may be a pressure transducer. Because for a given bias current the micro-bridge structure temperature will depend on the heat conduction due to the surrounding gases it can measure the pressure of those gases. The transducer may be thought of as a Pirani gauge.

25

If the transducer is a Pirani gauge the sacrificial material may be deposited to a depth of about $0.1\mu\text{m}$ by the method according to the first aspect of the invention. Possibly the sacrificial material may be deposited

30

to about any one of the following depths: 0.05 μm , 0.075 μm , 0.125 μm or 0.15 μm .

5 The transducer may be a flow transducer. The temperature of the micro-bridge structure for a given bias current will depend on how quickly heat is carried away by gas or liquid flows and therefore may be used as a flow transducer.

10 Of course, the transducer may be used as an IR transducer in applications such as Fire detection, intruder alarms, IR imaging or automatic inspection.

15 Indeed, the transducer may be an IR emitter since the temperature of the micro-bridge will vary when a suitable current is passed through it. Such an emitter may be useful for generating the IR signatures of objects, perhaps for the purpose of simulation.

There now follows by way of example only a detailed description of the invention with reference to the accompanying drawings of which:

20

Figure 1 shows a schematic view of a typical micro-bridge device;

Figure 2 shows cross sections through micro-bridge devices of three different types;

25

Figure 3 shows cross sectional views of a fabrication process for a micro-bridge device according to the present invention;

30 **Figures 4a, b, and c** show isometric views of the underside of the micro-bridge device of Figure 1; and

Figures 5 and 6 show scanning electron micrographs of micro-bridge structures according to the present invention.

- 5 Figure 1 shows a typical micro-bridge device, in this case a micro-bolometer. A main body 1 is provided and adapted to absorb radiation of the wavelength of interest incident upon it. Legs 2, 4 are provided to support the main body 1 above a substrate (not shown) and provide thermal isolation from that substrate. The substrate may be constituted as
10 a semi conductor wafer.

-
- Figure 2a shows a micro-bridge structure of the homogenous bridge type in which bridge is substantially of a uniform material. Some means of sensing is adapted to determine the temperature change of the bridge.
15 The means of sensing may be by way of passing a current through the bridge and measuring the current change.

- Figure 2b shows a film-on-support type of micro-bridge structure wherein (in this case) a metallic film 6 is provided on top of a supporting
20 bridge 8. The metallic film is shaped such that it acts a resistor. Vias 10, 12 must be provided through the bridge 8 to allow the resistor to be connected to processing electronics in a region underneath the bridge 8. Devices according to this design suffer from two disadvantages:

-
- Firstly, the metallic film reflects an amount of the incident radiation of
25 the wavelength of interest thus reducing the efficiency of the design. Secondly, the fabrication of the vias 10, 12 introduces extra critical processing steps which not only makes the devices more expensive but also reduces the yield of the process.

-
- 30 Figure 2c shows the structure of a micro-bridge device, or in this case a

micro-bolometer fabricated according to the invention wherein the metallic film 14 is provided on the under side of a bridge structure 16.

- Figure 3 outlines the process steps involved in fabricating the structure of
5 Figure 2c. The starting point of the process as shown in Figure 3a is a
fully processed CMOS wafer 20. The region 22 (which is only shown in
Figure 3a) is intended to represent CMOS circuitry provided in the
wafer 20. In the example described in relation to Figure 3 the initial
10 steps of the method comprise providing a metal layer on the upper surface
of the wafer. This metal layer connects the circuitry 22 to the micro-
bridge structure. This metal layer may or may not be required depending
on the number of metal layers available in the fabrication of the CMOS
circuitry 22.
- 15 At the start of the process described in relation to Figure 3a the wafer 20
has a Boron Phospho-Silicate Glass (BPSG) passivation layer 24 provided
on a top most surface.

- As shown in Figure 3b the first step of the disclosed method is pattern and
20 etch the BPSG passivation layer 24 to open vias 26 to the CMOS
circuitry 22. Once the vias 26 have been opened a pre-metal clean is
performed. This is achieved by the use of a 10:1 HF acid for 30 seconds.

-
- Once the clean has been performed metal is deposited and patterned.
25 Metal tracks 28 are formed in the vias 26. In one embodiment 5µm of
Al/1%Si was deposited having a resistivity of 60-70mΩ/sq.

- As shown in Figure 3d once the metal tracks 28 have been provided a
further passivation layer 30 is deposited on to the surface of the wafer 20.
30 In the embodiment shown the silicon nitride was deposited by Plasma

Enhanced Chemical Vapour Deposition (PECVD) to a depth of 2 μm .

The skilled person will appreciate that should the CMOS circuitry have enough metal layers to provide connections to the micro-bridge structure

5 which is to be fabricated that this point may be the start of the process.

Once the passivation layer 30 has been provided the sacrificial material 32 is provided onto the surface of the wafer 20. This sacrificial layer comprises a material that can be etched out from under the completed

10 micro-bridge structure without the required etch damaging either the structure, the sensor material, or any underlying CMOS circuitry.

Conveniently, this material may be a polyimide. A conventional polyimide may be used with a standard photoresist process to protect it during patterning, or a photo-imageable polyimide may be used which 15 may be directly patterned after exposure to ultraviolet light through a defining mask.

In the embodiment described, a conventional polyimide was used with a photoresist. The sacrificial layer is spin deposited and cured to a depth of

20 about 3 μm . After patterning it may be important to remove all traces of the resist layers, in the case of the embodiment described here this is achieved with an EKC etch. A small reduction in the thickness of the polyimide during this cleaning process can be tolerated.

25 Once the sacrificial material 32 has been provided it is patterned and etched as shown in Figure 3f. It should be noted that the passivation layer 30 is also etched in regions of the tracks 28 allowing contact to be made to the metal tracks 28.

30 After the patterning and etching has been performed a substantially 0.2 μm

thick layer of titanium 34 (a sensing material) is sputter deposited onto the surface of the wafer undergoing processing, as shown in Figure 3g. The metal layer is plasma etched to provide the desired structure. At the same time as the sensing material is etched to provide the desired structure the 5 sensing material is removed from the optical alignment targets (OATs) to aid coarse alignment of the subsequent layers.

A substantially 1 μ m thick layer of Silicon oxide 36 (SiO_2) (a support material providing the support element) is deposited onto the surface of 10 the titanium 34, as shown in Figure 3h. This oxide layer 36 is patterned and etched and it is ensured that the resists are removed using EKC.

In some embodiments of the process a matching layer (not shown) is deposited or grown on top of the oxide layer.

15 The next step is to ash the wafer undergoing processing to remove the sacrificial (polyimide) material. In the embodiment being described the ashing process lasts for about 12 minutes. This ashing process releases the support elements from the substrate and leaves a substantial void 38 20 between the titanium sensing material 34 and the passivation layer 30.

A final step of the process is to perform a rapid thermal anneal which lasts for 30 seconds and is performed at 400°C.

25 The skilled person will appreciate that Figures 1, 2c, and 4 show the structure of the micro-bridge device fabricated according to the process shown in Figure 3.

Referring mainly to Figure 1 the micro-bridge device 48 is substantially 30 square in plan. The square portion comprises a support element 50 which

is suspended above a substrate (not shown) by legs 2, 4. The legs 2, 4 are separated from the support element 50 by slits 52, 54 which ensure that the support element 50 has good thermal isolation from the substrate.

- 5 The structure of micro-bridge structure in Figure 1 is somewhat simplified when considering the structure of the legs 2, 4. In Figure 1 each leg 2, 4 comprises a planar portion 56 in the same plane as the support element 50 but separated from it by the slits 52, 54. In addition to the planar portion 56 there is provided an angular portion 58 which extends from the planar portion 56 at an angle toward the substrate over which the support element 50 is suspended. The planar portion of each leg 2, 4 is joined to the support element 50 by a connecting region. The angular portion is at a distal end from the connecting region.

- 15 The skilled person will appreciate that the specific structure of the legs 2, 4 fabricated by the disclosed method may differ slightly. The legs 2, 4 are formed by coating a depression etched into the sacrificial material with a sensing material and coating the sensing material with a support material.

20

On an under side of the support element 50 there is provided a metal track 60 (this is shown as the metallic film in Figure 2c) which forms a resistor having temperature dependent properties. The track 60 runs from the substrate, up a first leg 2 of the micro-bridge device, across the

- 25 connecting region (forming a connecting region of the resistor) joining the first leg 2 to the support element, meanders across the underside of the support element 50, across the other connecting region (forming another connecting region of the resistor) and down the other one of the legs 4.

- 30 As can be seen in Figures 4a and b in some embodiments the meanderings

of the track 60 have major portions running in directions substantially perpendicular to one another. The meanderings ensure that the length of the track 60 is maximised to increase the value of the resistance provided by the track 60, which in this case is about $3k\Omega$. The track is fabricated 5 from Titanium, having a temperature coefficient of resistance of about $0.35\%/\text{K}$.

Figure 4c shows an embodiment of the micro bridge structure with meanderings with major portions running in substantially only one 10 direction.

The scanning electron micrographs shown in Figures 5 and 6 show the track having a meandering nature with major portions running in directions transverse to one another. It is believed that this meandering 15 nature helps to prevent radiation of a particular polarisation passing through the micro-bridge.

The skilled person will appreciate that although the track is provided underneath the support material its path is visible, in Figures 5 and 6, on 20 a top surface of the support material due to the nature of the processes which are used to fabricate the micro-bridge structure.

The thickness of the SiO_2 (the support material) from which the support element is fabricated is made to be equivalent to one quarter of the 25 wavelength of the incident radiation of the wavelength of interest within the SiO_2 . The skilled person will appreciate that the wavelength of the radiation will be different in free space and within the SiO_2 . In this case the SiO_2 is made to be $1\mu\text{m}$ thick.

30 In use, an array of devices as shown in the Figures is provided and

- arranged to have radiation incident upon them. The support element 50 is tuned to absorb radiation in the wavelength range $8\mu\text{m}$ - $14\mu\text{m}$ (but may alternatively be tuned to other wavelengths) and therefore experiences a temperature change when such radiation is incident. This temperature
5 change causes the value of the resistance of the track 60 to change in a known manner and this change of temperature can be used by the circuitry to which the track 60 is connected to calculate the amount of radiation of the wavelength of interest that was incident upon the support element 50.
- 10 The leg 2, 4 ensure that the support element 50 is mechanically supported above the substrate but their design ensures sufficient thermal isolation so that the thermal mass of the substrate does not affect the temperature change of the support element.
- 15 Radiation of the wavelength of interest incident upon the micro-bridge enters the bridge structure. Eventually this radiation hits the metallic film 14 forming the track 60 which reflects the radiation back toward the top surface of the micro-bridge. The meanderings provided on the track 60 are thought to ensure that radiation having a polarisation of a
20 specific orientation does not pass through the track 60.
- Because the SiO_2 is $1/4$ of the wavelength of the radiation of interest the total optical path length from the top surface to the metallic film down to the lower surface and then back to the top surface is $1/2$ wavelength.
25 Therefore, destructive interference occurs in a region of the top surface ensuring that a high degree of absorption of the radiation of interest occurs.
- In some embodiments a matching layer may be provided on a top surface
30 of the micro-bridge adapted to match the surface to free space i.e.

377Ω/square. The skilled person will appreciate that when a wavefront passes between two mediums of differing refractive index a degree of reflection will occur. The matching layer helps to minimise this reflection and further increase the amount of radiation that is absorbed by the micro-bridge. It is important to ensure that the amount of radiation that is absorbed is maximised to ensure that the temperature change experienced by the support element 50 is as large as possible.

The skilled person will appreciate that although this application largely discusses absorption of radiation having a wavelength of 8μm-14μm the technology described may have wider applications. Detecting wavelengths of 8μm-14μm may be especially advantageous because it coincides with an atmospheric absorption window wherein there is little absorption by the atmosphere. The skilled person will further appreciate that there is a further absorption window between 3μm-5μm which may also be used. Further, it will be equally possible to fabricate devices which absorb radiation outside these wavelengths. In such devices the materials and structure of the bridge structure may simply need optimising for the wavelengths in question.

CLAIMS

1. A method of fabricating a micro-bridge device onto a substrate
5 including the steps:
 - a. providing a sacrificial material on a surface region of the substrate;
 - b. patternwise etching the sacrificial material;
 - c. providing a sensing material on a surface region of the sacrificial material;
 - d. providing a support material on a surface region of the sensing material; and
 - e. removing the sacrificial material leaving support material with the sensing material on its lower surface, substantially free standing above the substrate.
2. A method according to claim 1 wherein a micro-bolometer is formed and the sensing material provides the resistor of the micro-bolometer.
20
3. A method according to claim 1 wherein the sensing material forms the dielectric of a capacitor.

4. A method according to any one of the preceding claims which is
25 compatible with CMOS processing steps.

5. A method according to any one of the preceding claims in which step b of the process includes providing vias through the sacrificial material.
30

6. A method according to any one of the preceding claims in which the sacrificial material is polyimide.
 7. A method according to any one of the preceding claims in which
5 the sacrificial material is spin deposited and cured.
 8. A method according to any one of the preceding claims wherein the sacrificial material is applied to a thickness of about 3 μm .
 - 10 9. A method according to any one of the preceding claims wherein the sacrificial material is applied to a thickness of between about 1.5 μm and about 6 μm .
 10. A method according to any one of the preceding claims wherein the
15 —sacrificial—material is applied to a thickness of between about 2 μm and about 4.5 μm .
 11. A method according to any one of the preceding claims wherein an etch solvent is used to ensure that substantially all of the resist layers are
20 removed subsequent to deposition of the sacrificial material.
 12. A method according to claim 10 in which EKC is used as the etch solvent.
-
- 25 13. A method according to any one of the preceding claims in which the sensing material is any one of the following materials: titanium (Ti), amorphous silicon, vanadium oxide, platinum, nickel, aluminium, an alloy of platinum, an alloy of nickel, an alloy of aluminium.
 - 30 14. A method according to any one of the preceding claims wherein the

sensing material is deposited by sputter deposition

15. A method according to any one of the preceding claims wherein the sensing material is deposited to a thickness of about $0.2\mu\text{m}$.

5

16. A method according to any one of the preceding claims wherein the sensing material is applied to a thickness in the range of about $0.05\mu\text{m}$ to about $0.3\mu\text{m}$.

10 17. A method according to any one of the preceding claims wherein the sensing material is applied to a thickness in the range from about $0.1\mu\text{m}$ to about $0.25\mu\text{m}$.

15 18. A method according to any one of the preceding claims wherein the sensing material is provided to have a resistance of $3.3\Omega/\text{sq}$.

19. A method according to any one of the preceding claims wherein the sensing material is provided to have a resistance of about $1.5\Omega/\text{sq}$ to about $6\Omega/\text{sq}$.

20

20. A method according to any one of the preceding claims wherein the sensing material is provided to have a resistance of about $2.5\Omega/\text{sq}$ to about $4.5\Omega/\text{sq}$.

25 21. A method according to any one of the preceding claims in which step C. of the method includes the removal of the sensing material from optical alignment targets (OAT) provided on the substrate.

30 22. A method according to any one of the preceding claims wherein the support material is deposited onto the surface region of the sensing

material.

23. A method according to claim 22 wherein the support material is deposited by any one of the following process, Plasma enhanced chemical vapour deposition, low pressure chemical vapour deposition, or sputtering.

24. A method according to any one of the preceding claims wherein the support material is applied to a depth of about $1\mu\text{m}$.

10

25. A method according to any one of the preceding claims wherein the support material is applied to about any one of the following depths $\frac{1}{2}\mu\text{m}$, $2\mu\text{m}$, $3\mu\text{m}$, $4\mu\text{m}$, $5\mu\text{m}$.

15

26. A method according to any one of the preceding claims wherein the method applies the support material to an accuracy of about $\pm 10\%$.

20

27. A method according to any one of the preceding claims wherein the method comprises applying the support material to have a thickness of about $\frac{1}{4}\lambda$ where λ is the wavelength of the incident radiation of interest within the support material.

25

28. A method according to any one of the preceding claims wherein the method comprises providing the sacrificial material to a depth of about

29. A method according to any one of the preceding claims wherein the support material is patterned and etched to provide the necessary structures.

30

30. A method according to claim 29 wherein the resists used to pattern and etch the support material are removed by an etch solvent.
31. A method according to claim 30 wherein the etch solvent is EKC.
- 5 32. A method according to any one of the preceding claims wherein a silicon oxide is used as the support material.
- 10 33. A method according to any one of the preceding claims wherein the sacrificial material is removed by ashing.
34. A method according to claim 33 wherein an oxygen plasma performs the ashing process
- 15 35. A method according to any one of the preceding claims wherein a thermal anneal on the substrate.
36. A method according to claim 35 wherein the thermal anneal is performed after step e. of the method.
- 20 37. A method according to claim 35 or 36 wherein the anneal is one of the following processes: a rapid thermal anneal, a furnace anneal.
38. A method according to any one of the preceding claims wherein the sensing material is provided in tracks.
-
- 25 39. A method according to claim 38 which comprises providing the tracks such that incident radiation having a specific polarisation cannot pass through the tracks.
- 30 40. A method according to claim 38 or 39 in which the tracks are

provided such that they have lengths running in directions transverse to one another.

41. A method according to any one of the preceding claims wherein a
5 matching layer is provided in a region above the support material, adapted
to absorb incident radiation of the correct wavelength.

42. A method according to any one of the preceding claims wherein an encapsulated package is provided for the micro-bridge structure.

10 43. A method according to claim 42 comprising filling the encapsulated package with a gas having a low thermal conductivity.

44. A method according to claim 43 wherein the gas is xenon.

15 45. A method according to claim 42 comprising evacuating the encapsulated package.

20 46. A method according to any one of the preceding claims comprising providing a reflective layer.

47. A method according to claim 46 comprising providing the reflective layer on-a-top-region-of-the-substrate-before-the-sacrificial-material-is provided.

25 48. A method according to claim 46 or 47 wherein the reflective layer is provided from any one of the following materials: Aluminium, titanium, nichrome, platinum, nickel or an alloy of any of these metals.

30 49. A micro-bridge structure having a substrate above which there is

provided a support element of the micro-bridge structure, on the underside of the support element there is provided a sensing material, the sensing material being supported above the substrate by the support element but connected at connecting regions to tracks on the substrate.

5

50. A structure according to claim 49 wherein the support element comprises a region of silicon oxide (SiO_2).

10 51. A structure according to claim 49 or 50 wherein the support element is substantially square in plan.

52. A structure according to claim 51 wherein the support element has dimensions of substantially 50 μm for its sides

15 53. A structure according to claim 51 wherein the support element has sides in the range of about 25 μm to about 100 μm .

54. A structure according to claim 51 wherein the support element has sides in the range 35 μm to about 75 μm .

20

55. A structure according to any one of claims 49 to 54 wherein the support element is provided with leg portions adapted to suspend the support element above the substrate.

25 56. A structure according to claim 55 wherein the sensing material is provided on the underside of the leg portions.

57. A structure according to any one of claims 49 to 56 wherein, the sensitive material forms a resistor.

30

58. A structure according to claim 57 wherein the resistor is connected to the source of a CMOS transistor provided in the substrate.
59. A structure according to claim 57 or 58 wherein the resistor has a resistance of about $3\text{k}\Omega$.
60. A structure according to claim 57 or 58 wherein the resistor has a resistance in the range of about $1.5\text{k}\Omega$ to about $6\text{k}\Omega$.
- 10 61. A structure according to claim 57 or 58 wherein the resistor has a resistance of about $2\text{k}\Omega$ to about $4.5\text{k}\Omega$.
- 15 62. A structure according to any one of claim 57 to 61 wherein the resistor is provided as a track on the support element.
63. A structure according to claim 62 wherein the track has a meandering structure
64. A structure according to claim 63 wherein the meandering structure has portions in transverse directions.
- 20 65. A structure according to claim 64 wherein the transverse directions are substantially perpendicular to one another.
- 25 66. A structure according to any one of claims 49 to 56 wherein the sensing material forms the dielectric of a capacitor.
67. A structure according to any one of claims 49 to 66 wherein the sensing material is a metal.

68. A structure according to claim 67 wherein the sensing material is any one of the following titanium, platinum, nickel, aluminium, an alloy of any one of the aforementioned metals.
- 5 69. A structure according to any of claims 49 to 66 wherein the sensing material is either amorphous silicon or vanadium oxide.
70. A structure according to any one of claims 49 to 66 wherein the sensing material is a ferro-electric material.
- 10 71. A structure according to any one of claims 49 to 70 wherein the thickness of the support element is tailored to be substantially $\frac{1}{4}\lambda$ of the incident radiation within the material of the support element.
- 15 72. A structure according to any one of claims 49 to 71 wherein the support element has a thickness of about $1\mu\text{m}$.
73. A structure according to any one of claims 49 to 71 wherein the support element has a thickness in the range of about $0.5\mu\text{m}$ to $2\mu\text{m}$.
- 20 74. A structure according to any one of claims 49 to 71 wherein the support element has a thickness in the range of about $0.75\mu\text{m}$ to about $1.5\mu\text{m}$.
-
- 25 75. A structure according to any one of claims 49 to 67 wherein the support element is suspended substantially one quarter of the wavelength of the radiation which is desired to measure above the substrate.
76. A structure according to any one of claims 49 to 75 which
- 30 comprises a matching layer which is provided on an uppermost surface of

the support element.

77. A structure according to any one of claims 49 to 76 in which there is provided a reflective layer.

5

78. A structure according to claim 77 wherein the reflective layer is provided on a top region of the substrate.

79. A structure according to claim 77 or 78 wherein the reflective layer 10 is provided from any one of the following materials: Aluminium, titanium, nichrome, platinum, nickel or an alloy of any of these metals

80. A transducer incorporating a micro-bridge structure according to any one of claims 49 to 79.

15

81. A transducer according to claim 80 wherein the transducer is a pressure transducer.

82. A transducer according to claim 80 or 81 wherein the transducer is 20 a Pirani gauge.

83. A transducer according to claim 80 wherein the transducer is a flow transducer.

25 84. A transducer according to claim 80 wherein the transducer is an IR transducer.

85. A transducer according to claim 80 wherein the transducer is an IR emitter.

86. A transducer substantially as described herein with reference to the accompanying drawings.

87. A method of fabricating a micro-bridge structure substantially as
5 described herein with reference to the accompanying drawings.

88. A micro-bridge structure substantially as described herein with
reference to the accompanying drawings.

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5

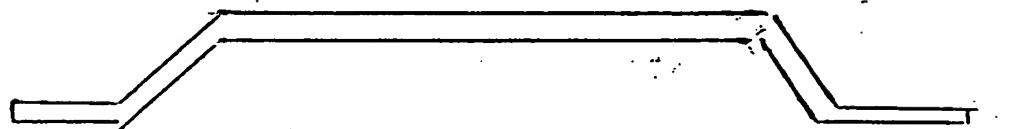
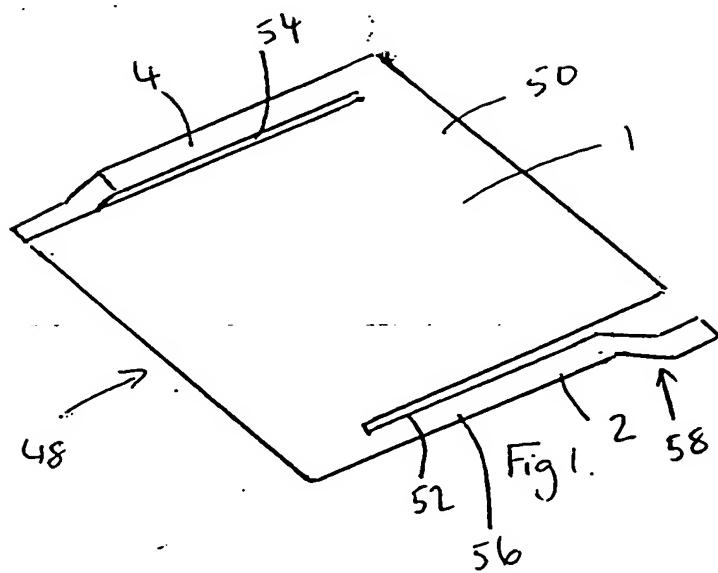
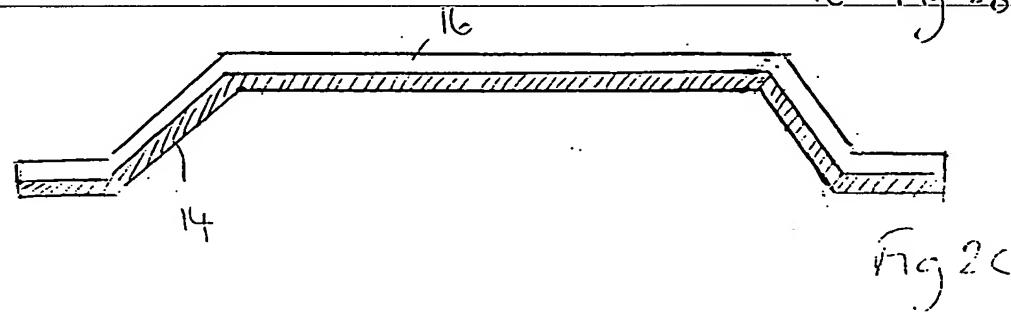
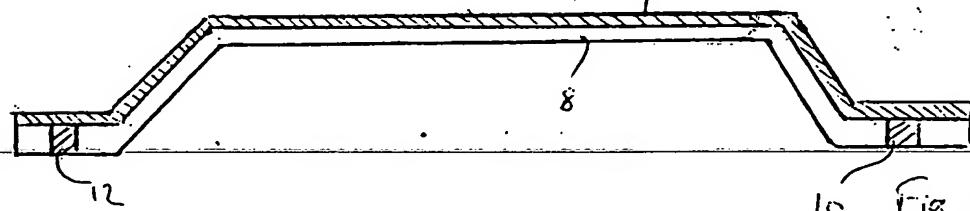
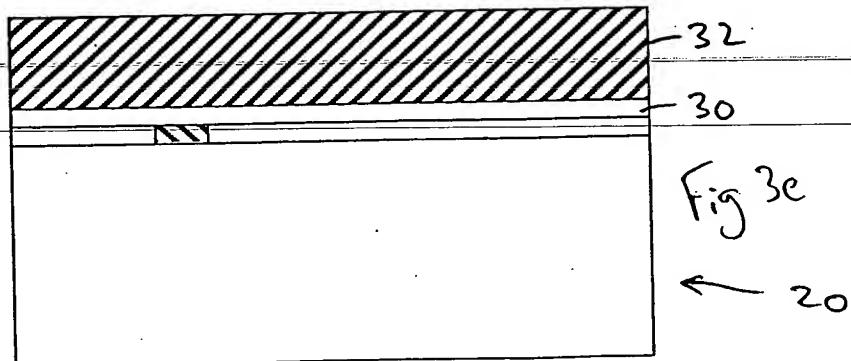
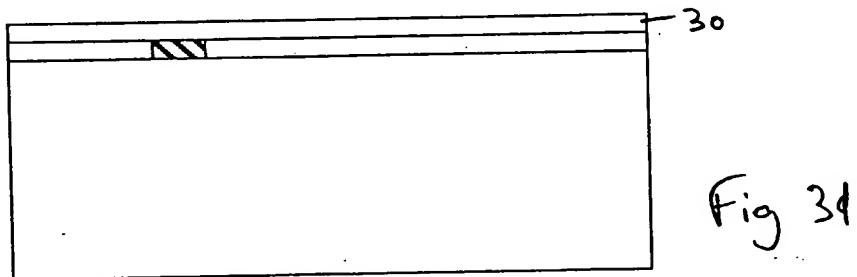
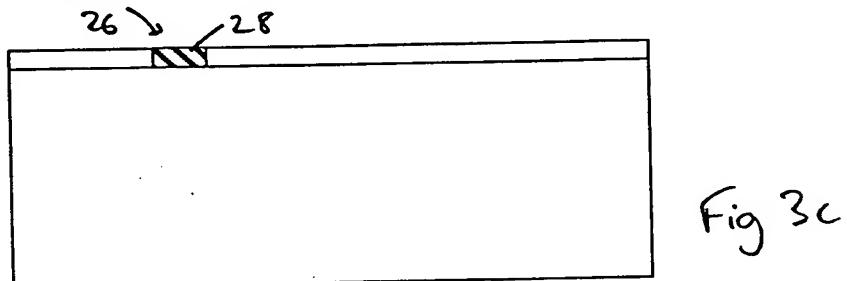
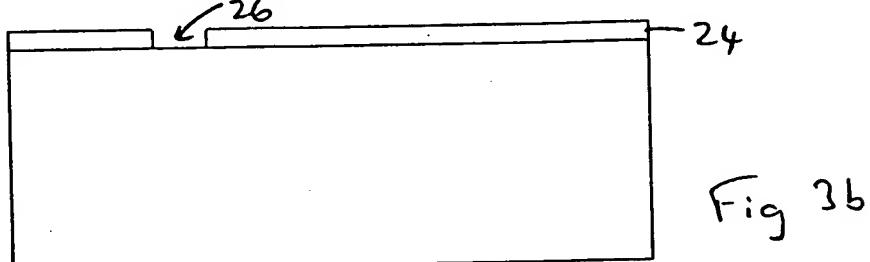
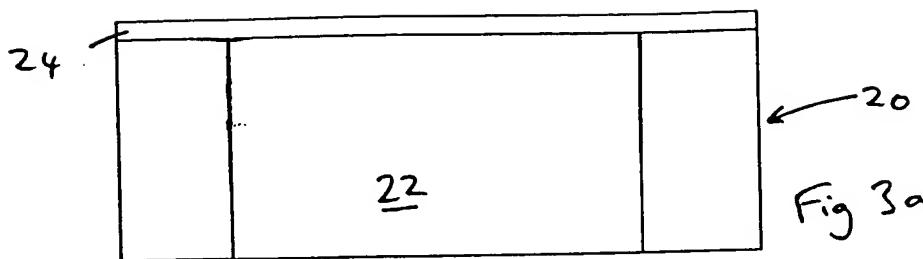


Fig 2a

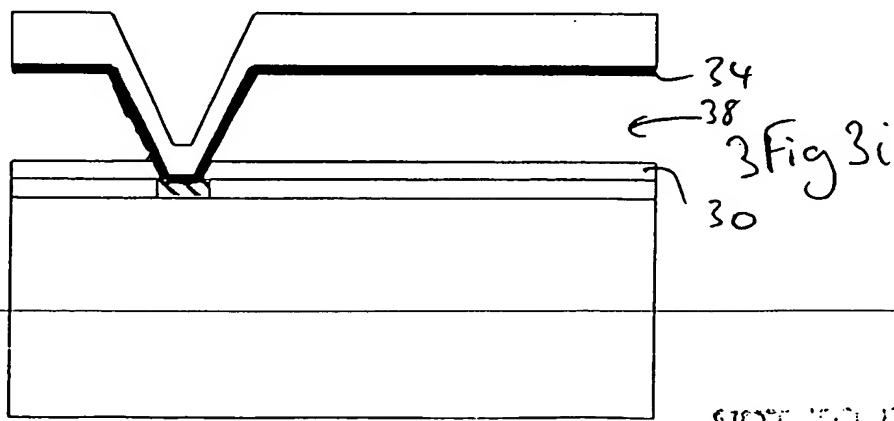
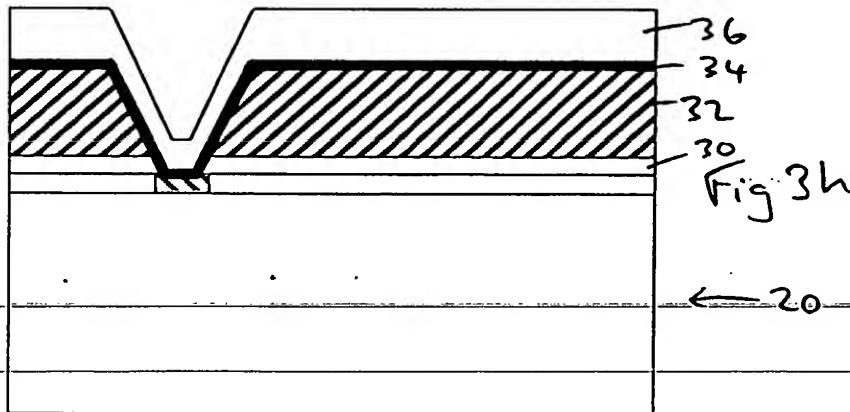
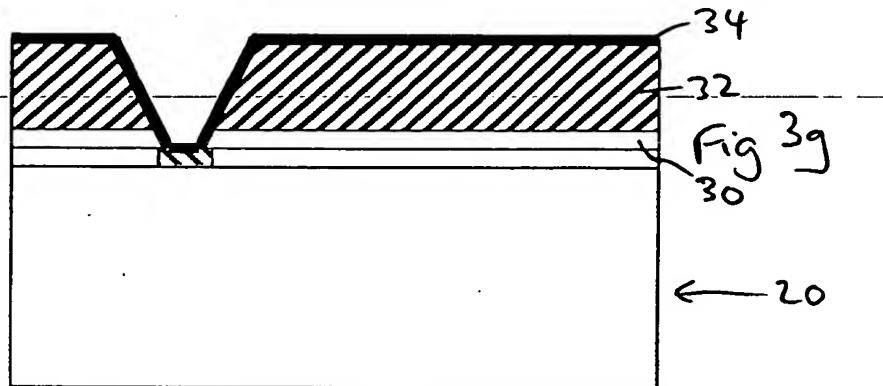
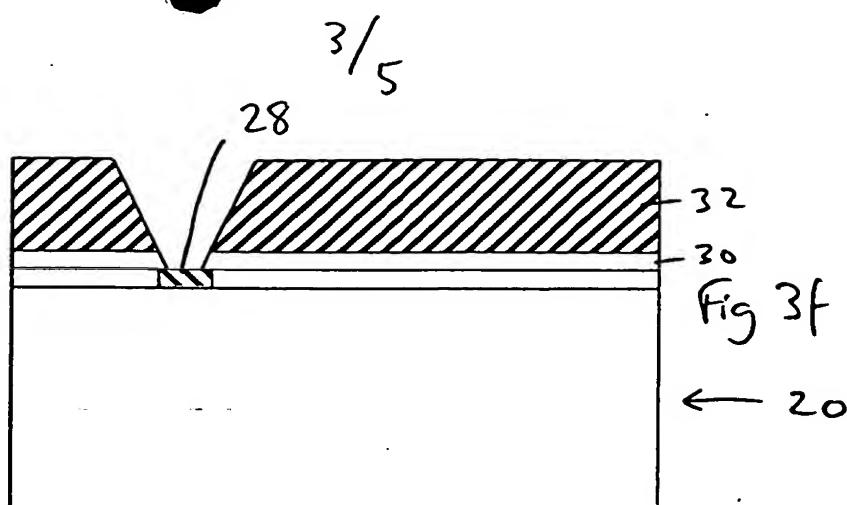


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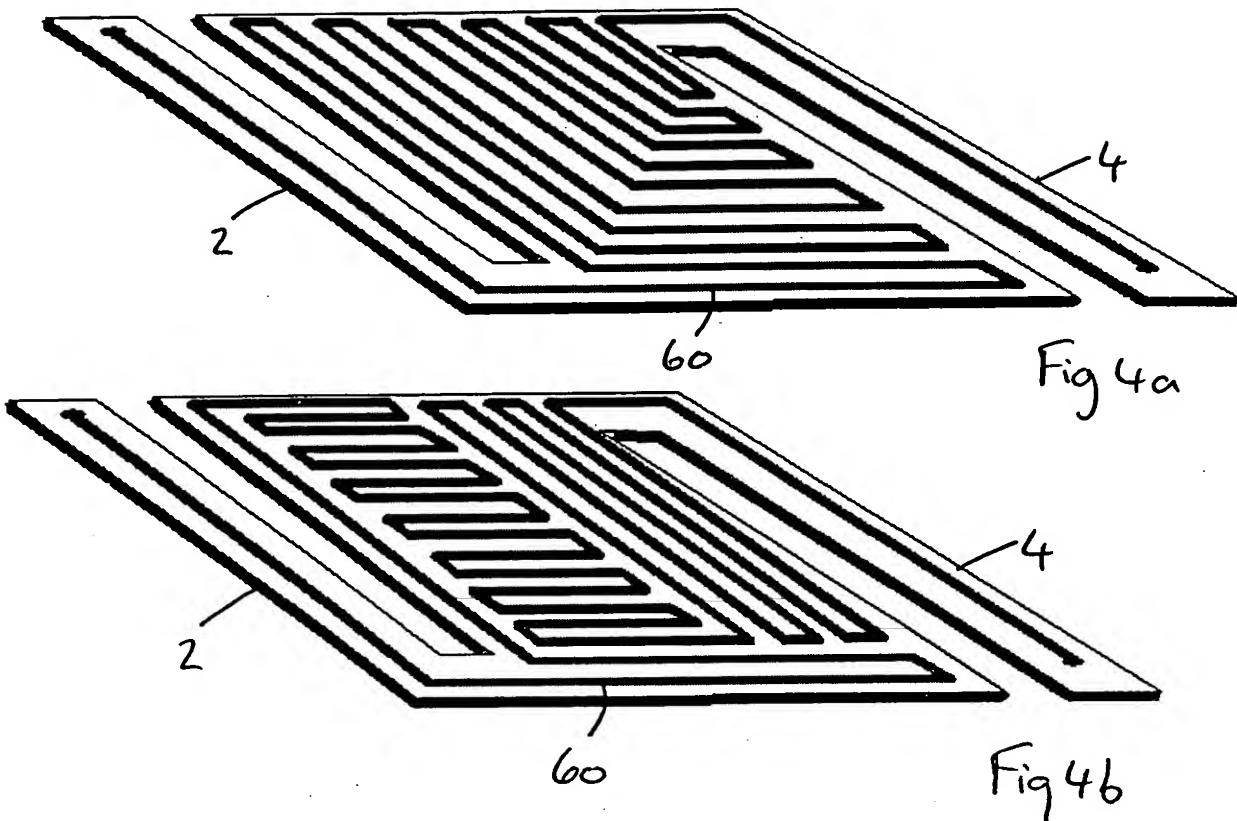


Fig 4a

Fig 4b

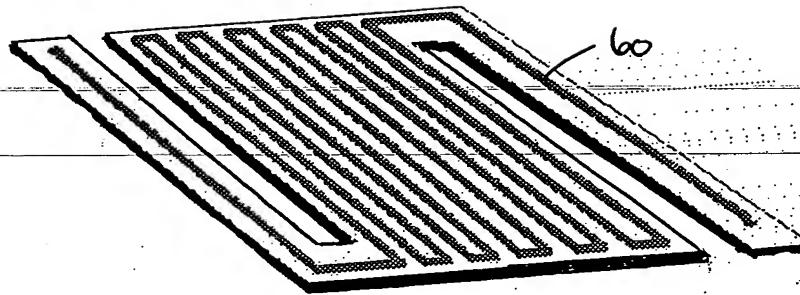


Fig 4c

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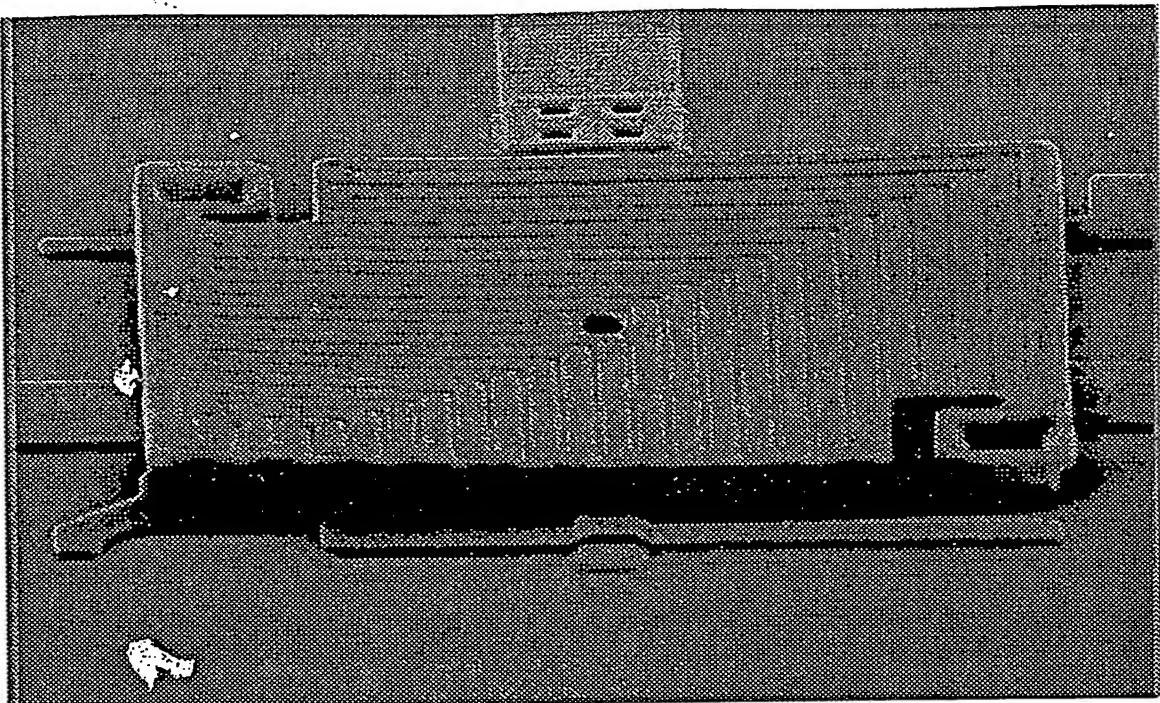


Fig 5

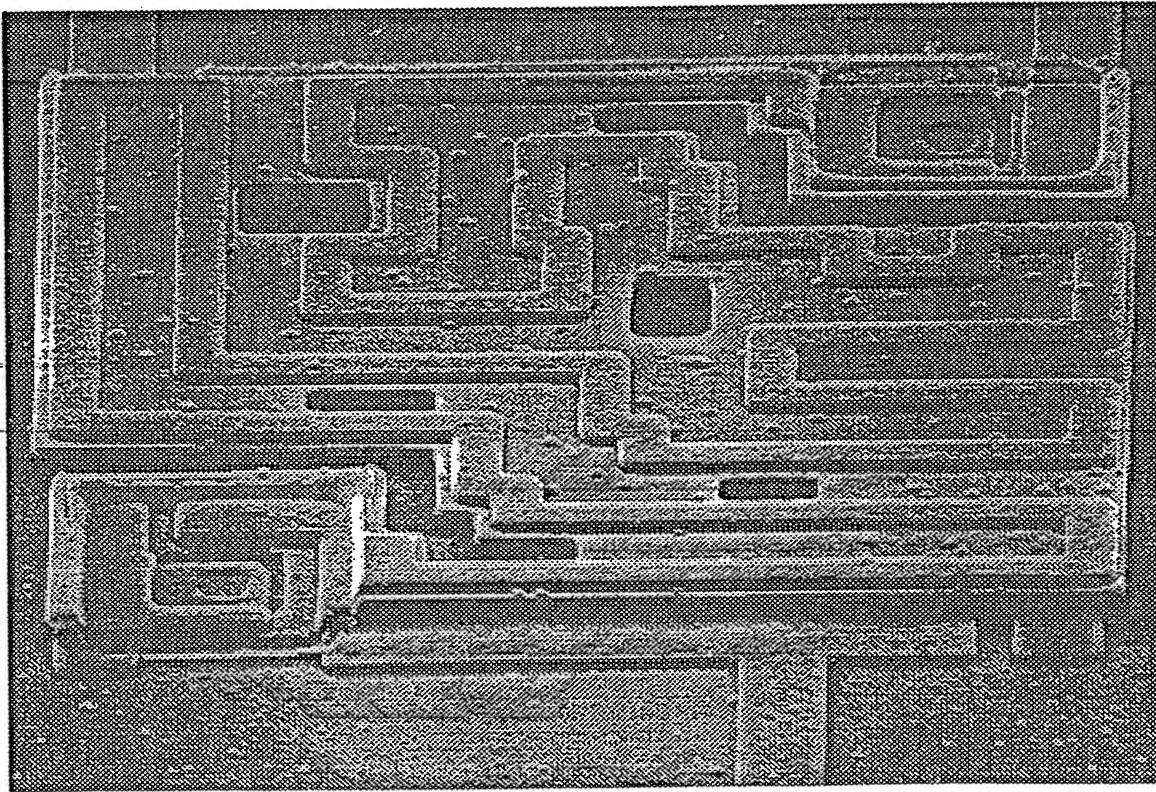


Fig 6

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